The Role of Science in Managing the Arbuckle-Simpson Aquifer

Noel Osborn

State of Oklahoma
OWRB
Water Resources Board
the water agency

Early Statehood

- Scientific Understanding:
  - Underground water
- Question:
  - Where is the water?

Early Statehood

- Scientific Information and Tools:
  - Surface geology; geographic features (springs)
  - Water wells
  - Field reconnaissance
- Studies:
  - 1905: “Geology and Water Resources of Oklahoma” USGS Water Supply Paper 148
- Management:
  - Reasonable use

1973 Groundwater Law

- Scientific Understanding:
  - Groundwater is a dynamic system
  - Water yields vary by aquifer (groundwater basin)
- Question:
  - How much water can we pump from a basin?

1973 Groundwater Law

- Scientific Information and Tools:
  - Aquifer properties, recharge, and discharge
  - Computer models
- Studies:
  - 1978: Hydrologic Investigation of the Tillman Terrace Groundwater Basin
- Management:
  - Maximum Annual Yield

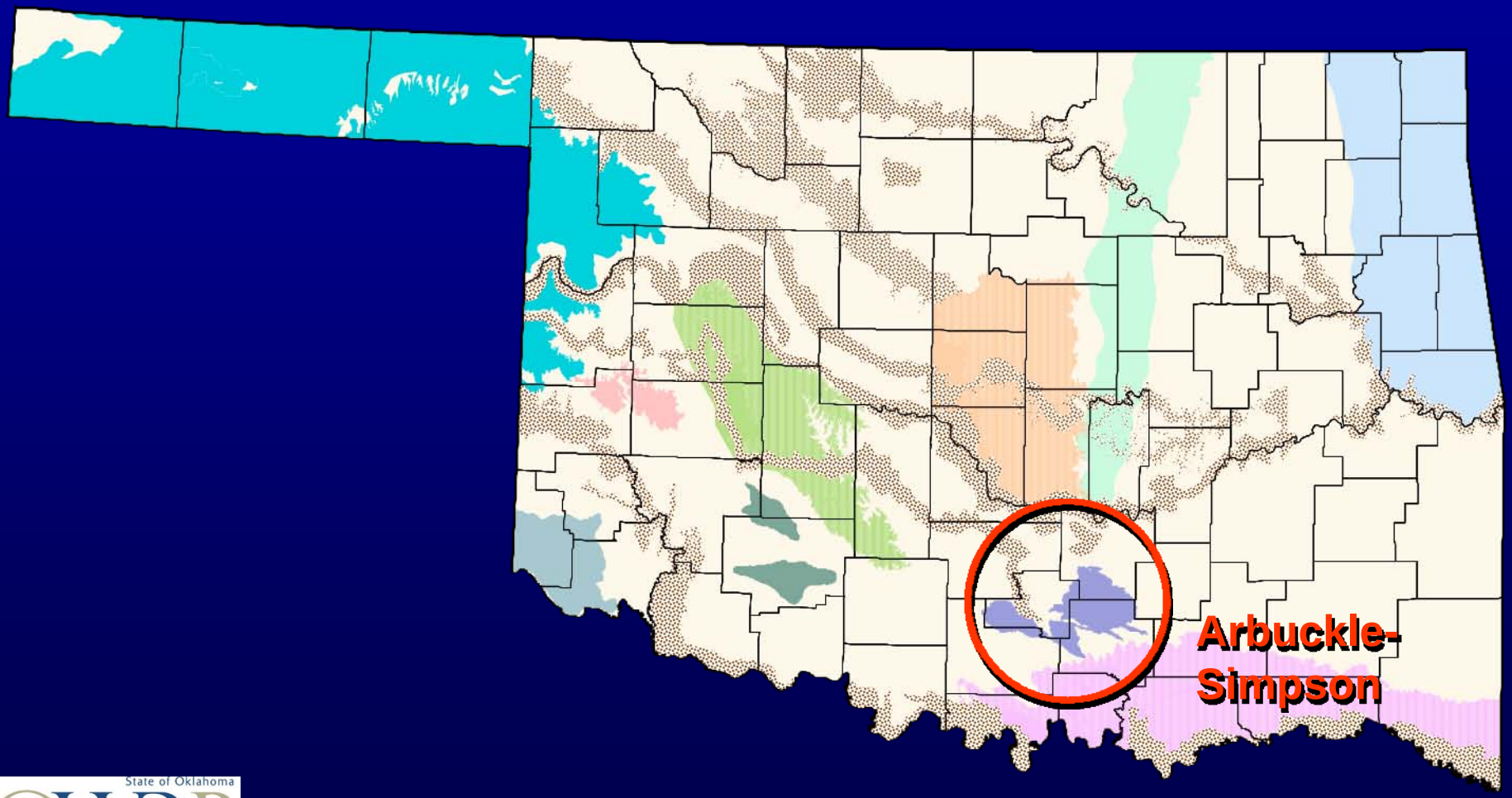
2003 Senate Bill 288

- Scientific Understanding:
  - Groundwater withdrawals can impact surface water flow and the environment
- Question:
  - How much water can we pump without reducing the natural flow of streams?

2003 Senate Bill 288

- Scientific Information and Tools:
  - Hydrologic system, ecosystems and habitat, climatic variability, social sciences
  - More sophisticated computer models and other new technologies
- Studies:
  - Arbuckle-Simpson Hydrology Study
- Management:
  - Maximum Annual Yield
  - Management Strategies

Major Aquifers in Oklahoma



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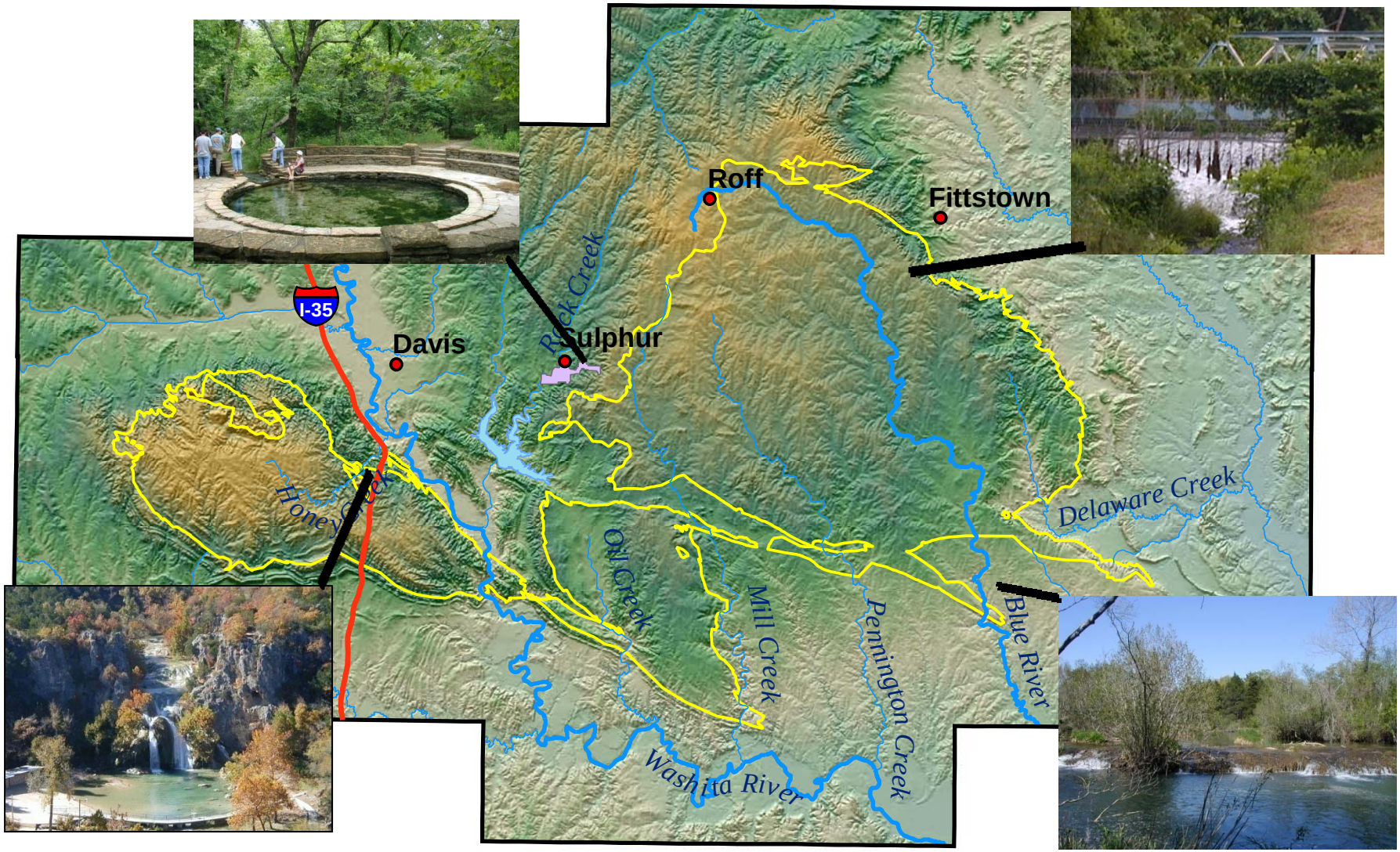
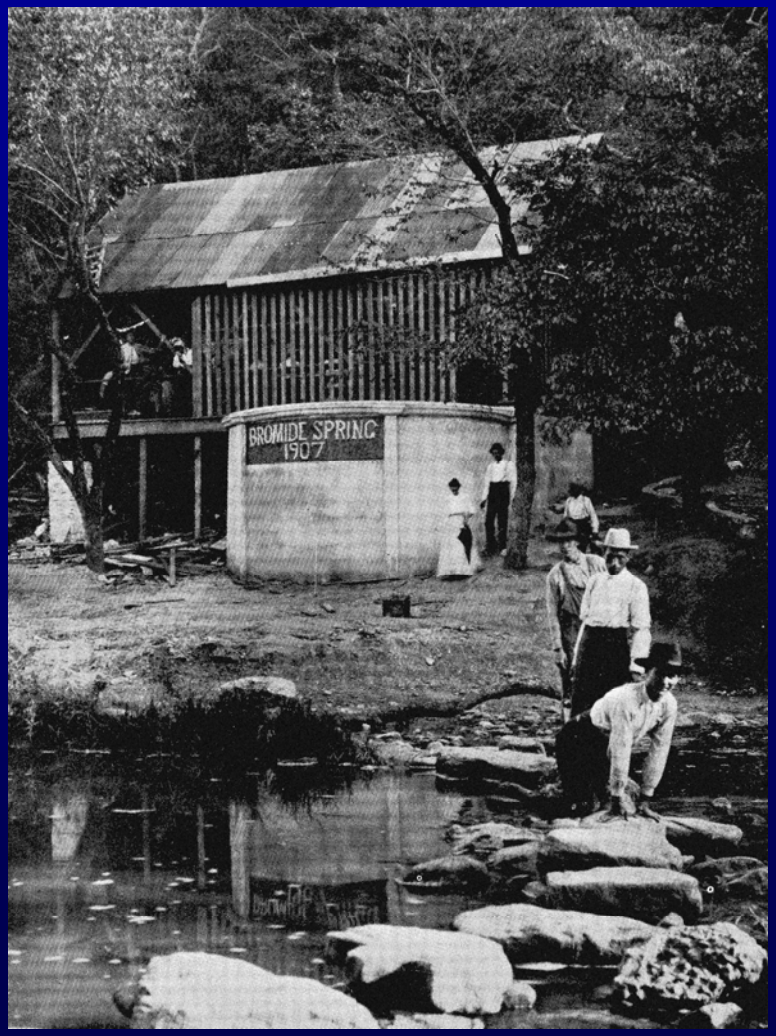
the water agency

Arbuckle-Simpson Aquifer Outcrop

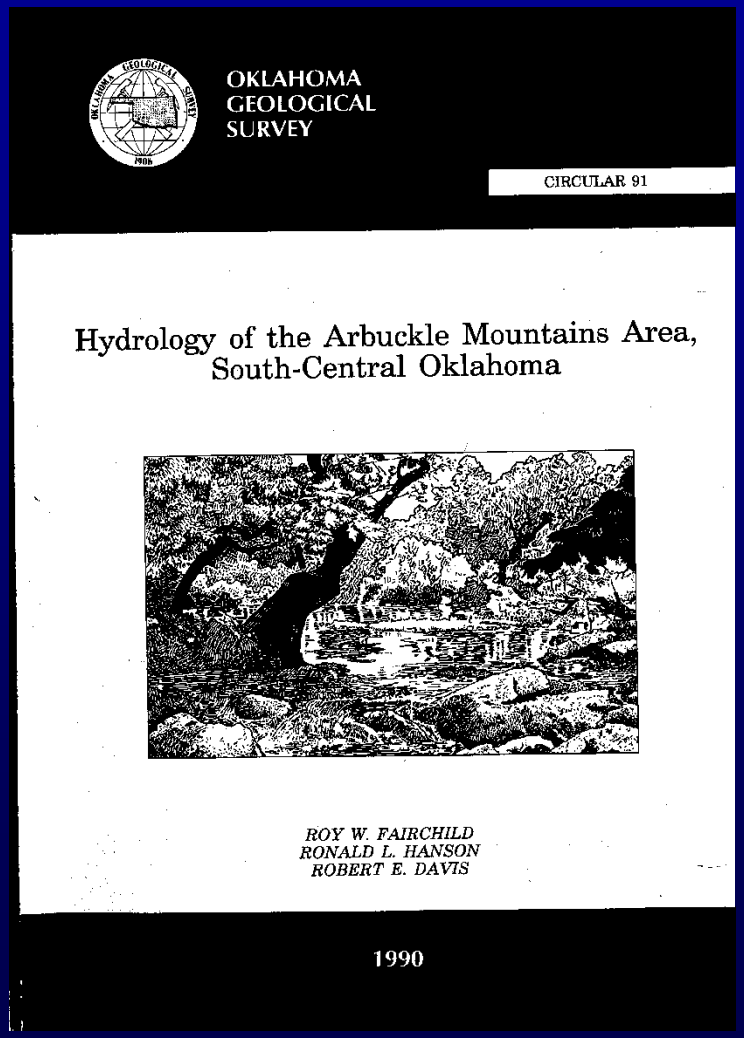


Sulphur Springs



Artesian Wells

Hydrologic Investigation


OKLAHOMA
GEOLOGICAL
SURVEY

CIRCULAR 91

Hydrology of the Arbuckle Mountains Area,
South-Central Oklahoma

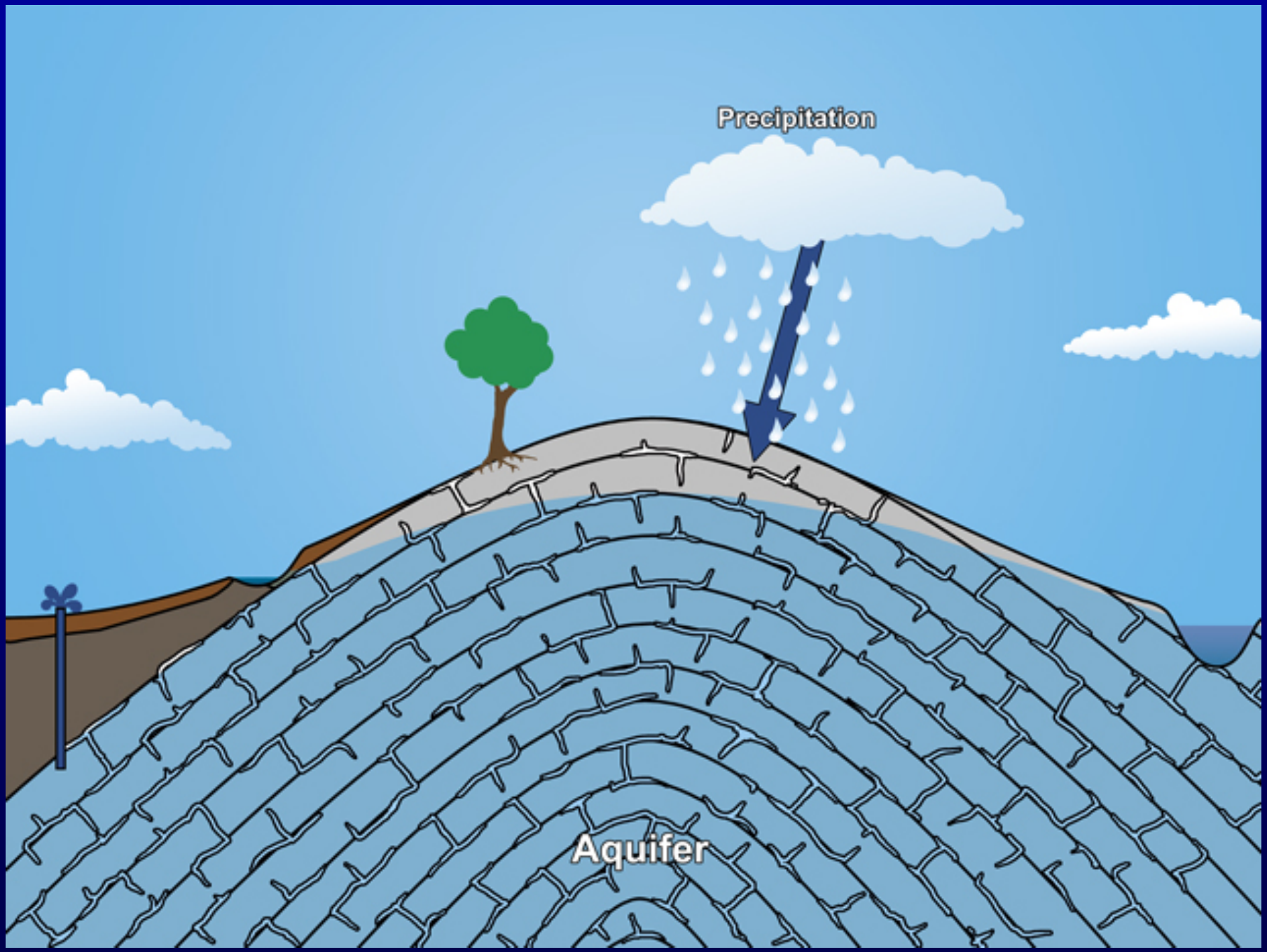
ROY W. FAIRCHILD
RONALD L. HANSON
ROBERT E. DAVIS

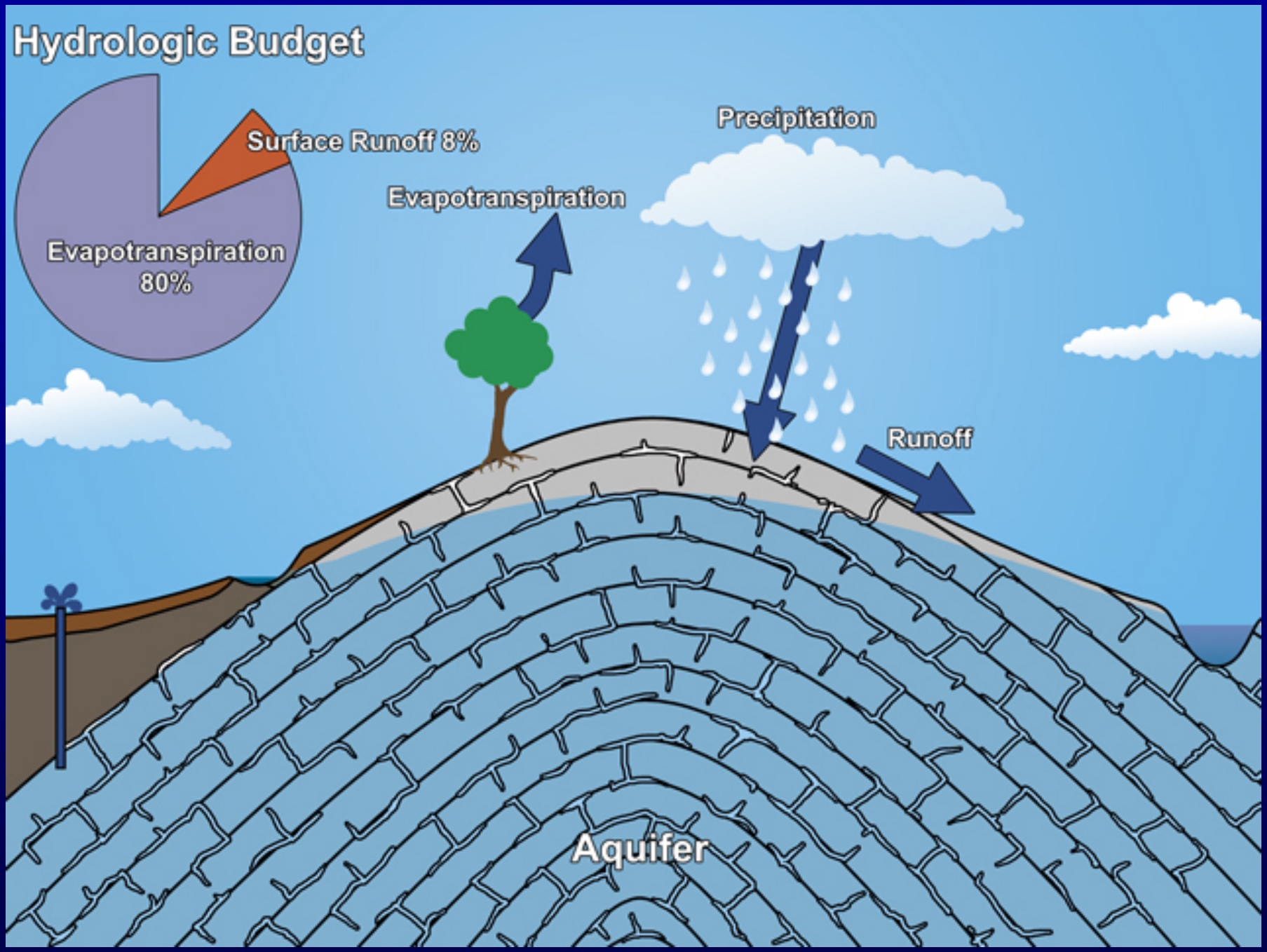
1990

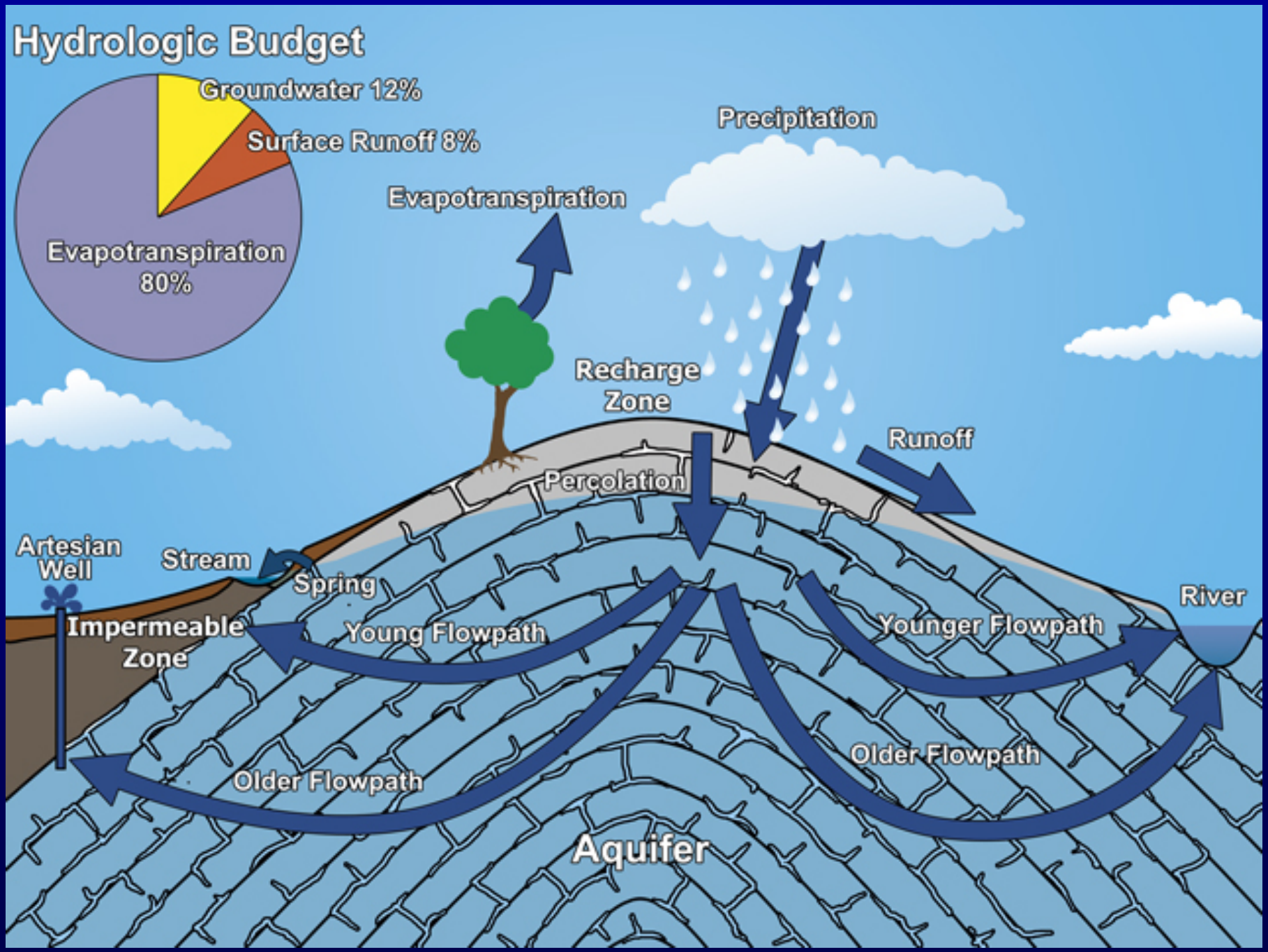
Central Oklahoma Water Authority
Proposed Pipeline

Senate Bill 288

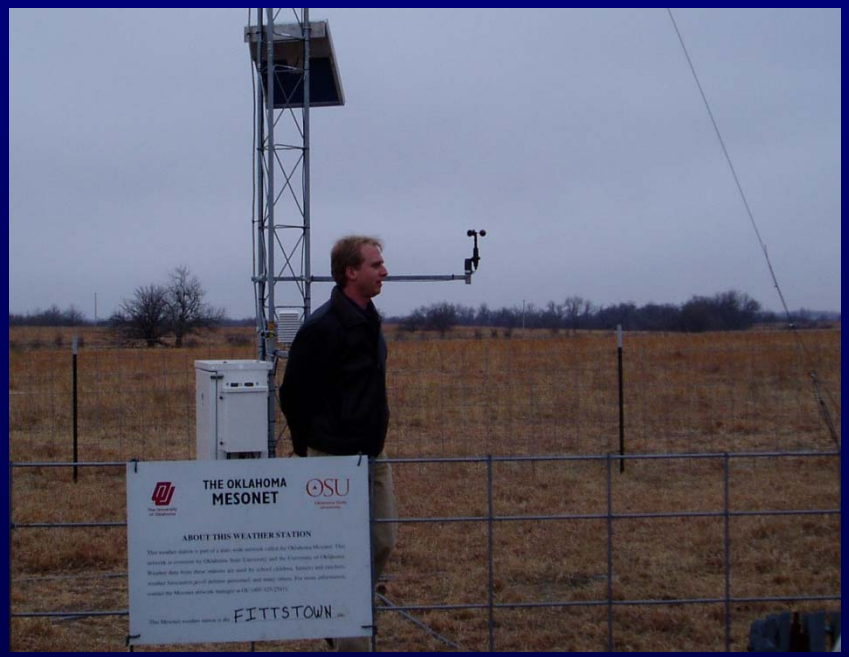
- Moratorium
- Conducts and completes a hydrological study
- Approves a maximum annual yield that will not reduce the natural flow of water from springs or streams emanating from the basin


Precipitation
Aquifer


Hydrologic Budget
Surface Runoff 8%
Evapotranspiration
80%
Precipitation
Evapotranspiration
Runoff
Aquifer


Hydrologic Budget
Groundwater 12%
Surface Runoff 8%
Evapotranspiration 80%
Precipitation
Evapotranspiration
Recharge Zone
Runoff
Percolation
Artesian Well
Stream
Spring
River
Impermeable Zone
Young Flowpath
Younger Flowpath
Older Flowpath
Older Flowpath
Aquifer


Geology
Surface Water
Climate
Ground Water


THE OKLAHOMA
MESONET
OSU
ABOUT THIS WEATHER STATION
FITTSTOWN


Arbuckle-Simpson Regional Geology

Putting the pieces together

Geology:

- Petroleum information
- Fracture properties
- Geophysics
- Deep test well
- 3-D geologic modeling

Surface Water:

- 3 USGS gages
- Baseflow monitoring
- Rainfall-runoff modeling
- Instream flow study

Ground Water:

- Water-level monitoring
- Water chemistry
- Age-dating
- Aquifer tests
- Water use
- Ground-water modeling

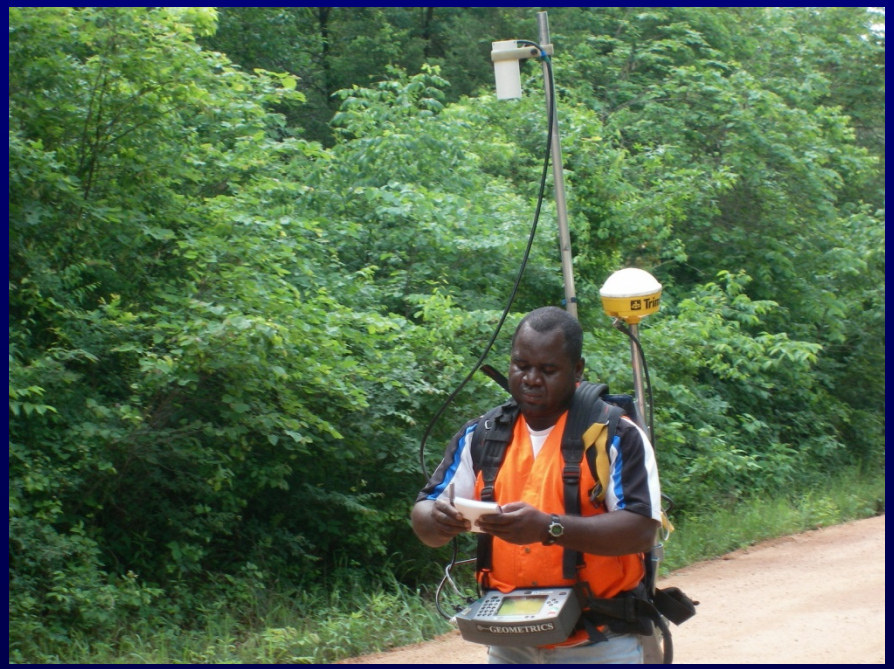
Climate:

- Fittstown Mesonet station
- Hydrologic budget
- Tree-ring analysis

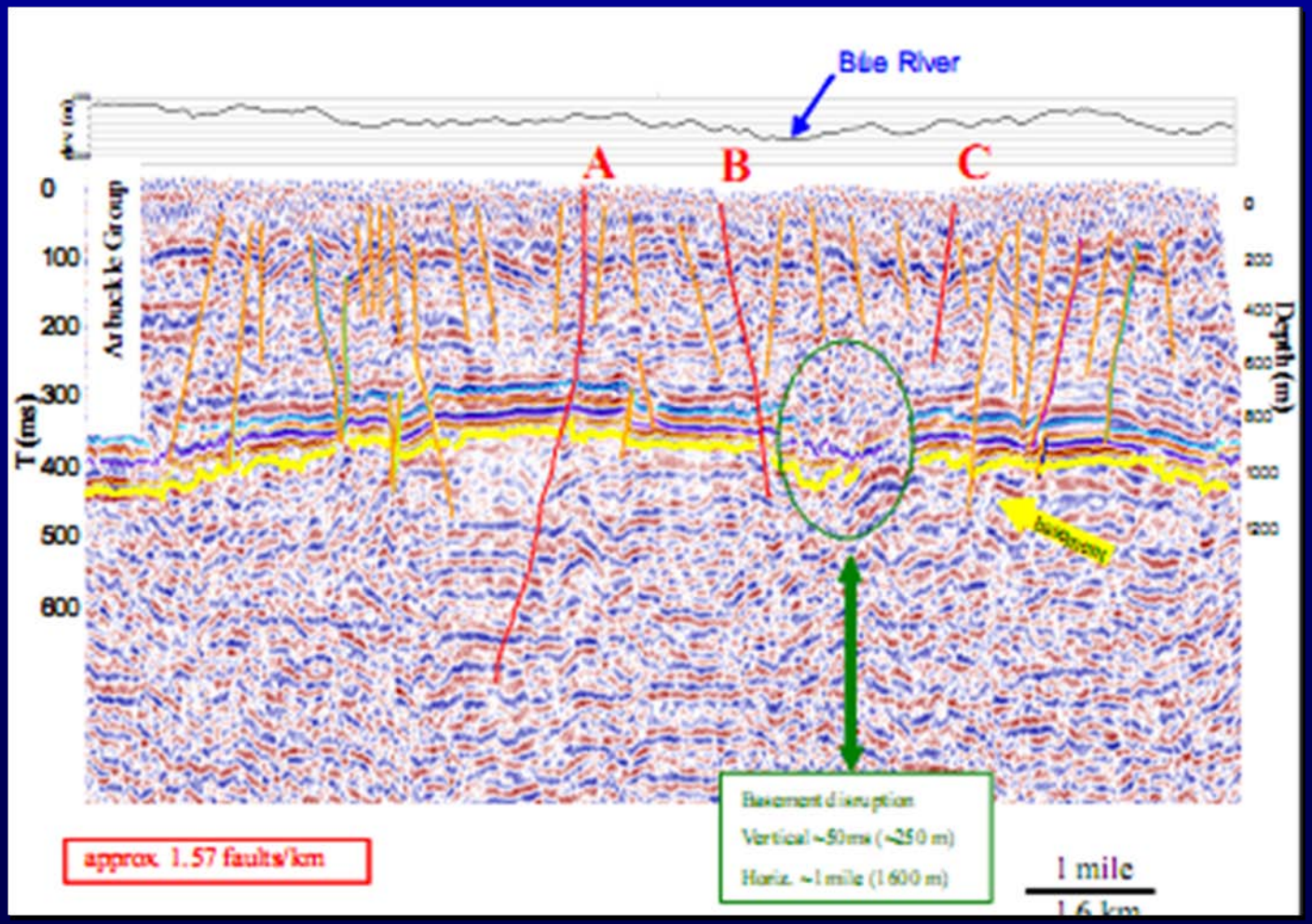

Geology


Cross Section Through the Arbuckle Anticline
Showing Geological Structure Along I-35
SOUTH
YOU ARE HERE
NORTH
THESE ROCKS WERE ORIGINALLY DEPOSITED AS HORIZONTAL LAYERS OF SEDIMENT IN A MARINE SEA. THE SEDIMENTARY LAYERS OVERLIE IGNEOUS ROCKS (PURPLE) OF A VOLCANIC ORIGIN. ABOUT 285 MILLION YEARS AGO. THE STRATA WERE FOLDED BY TECTONIC COMPRESSION INTO A HIGH MOUNTAIN RANGE. OVER EONS OF TIME, WIND & WATER HAVE WORN AWAY THE HIGH MOUNTAINS, LEAVING ONLY THE SMALL HILLS THAT PRESENTLY SHAPE THE SURROUNDING COUNTRYSIDE
THESE GEOLOGICAL SIGNS WERE SPONSORED BY THE ARDMORE GEOLOGICAL SOCIETY AND ERECTED WITH THE APPROVAL OF THE STATE HIGHWAY DEPARTMENT

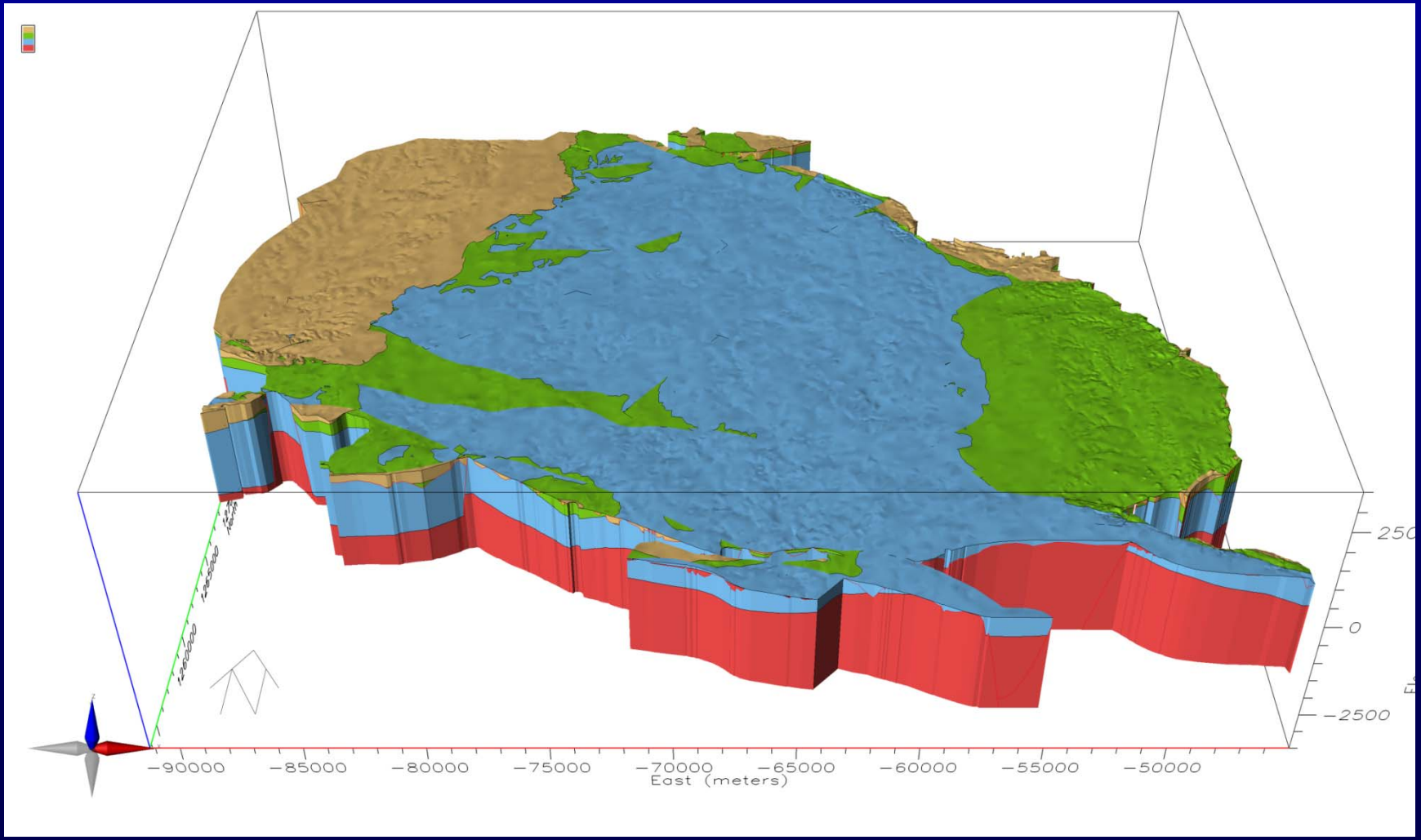

C-FYZF


GEOMETRICS

Geophysical Data



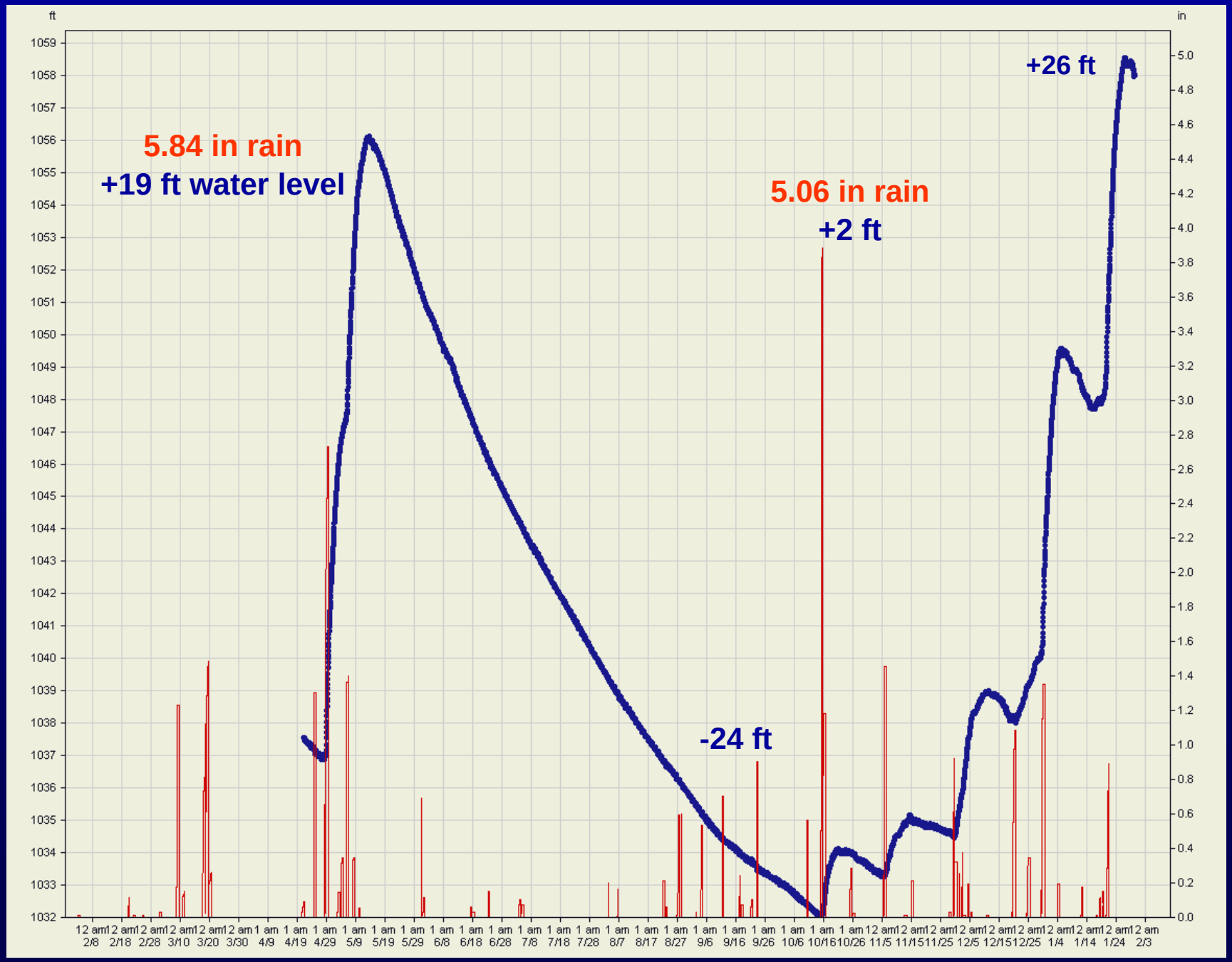
3D Geologic Model




Climate

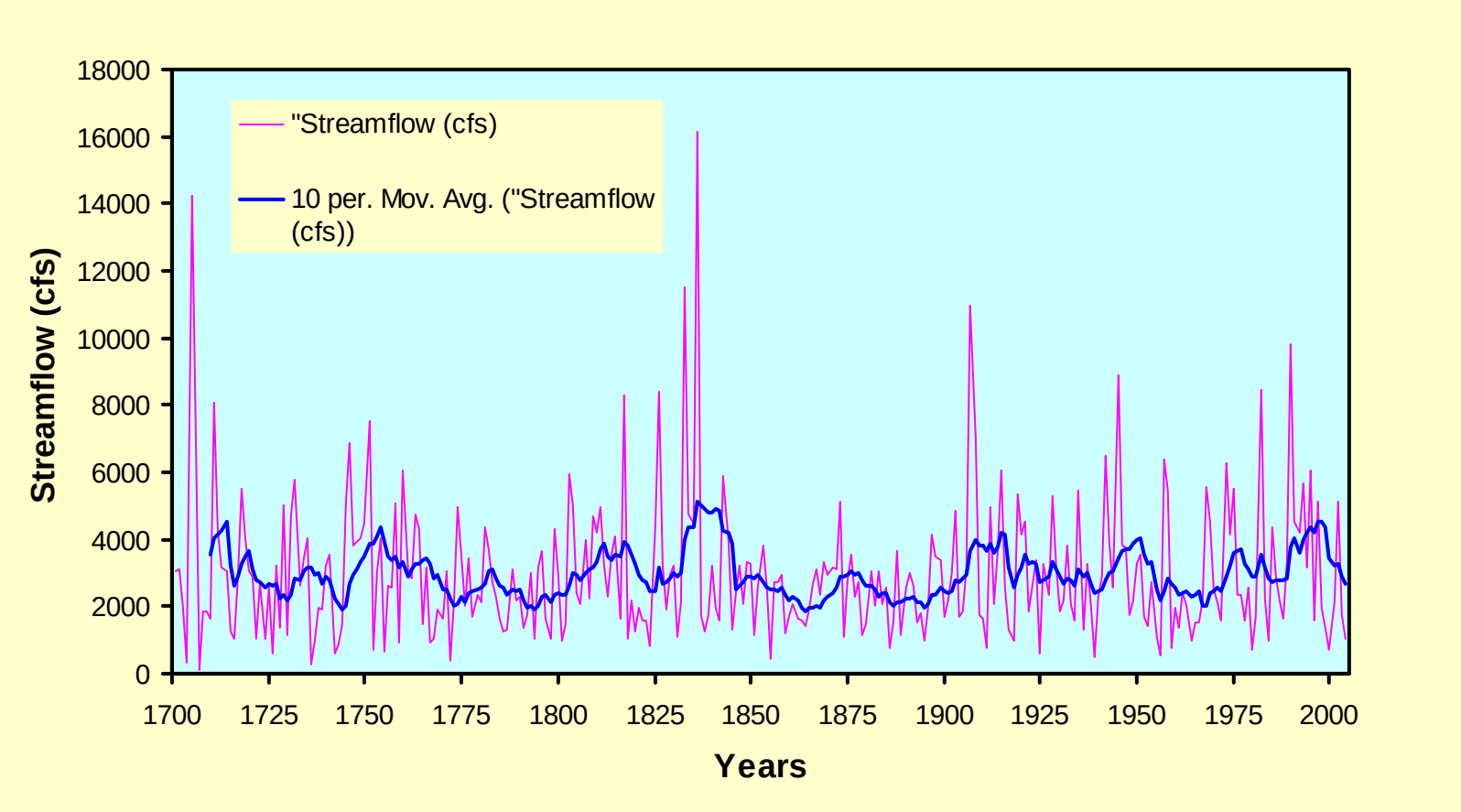
Fittstown Mesonet Station

- Temperature
- Rainfall
- Humidity
- Wind Speed
- Wind Direction
- Barometric Pressure
- Solar Radiation
- Soil Temperature
- Soil Moisture
- Ground-Water Elevation


ft
in
5.84 in rain
+19 ft water level
5.06 in rain
+2 ft
+26 ft
-24 ft


HISTORIC LOG BUILDING
POST OAK
1623
1700
1843

Reconstructed Streamflow:
Blue River near Blue




Groundwater

Geochemical Study

In cooperation with the Oklahoma Water Resources Board

Geochemistry of the Arbuckle-Simpson Aquifer

Introduction

The Arbuckle-Simpson aquifer (fig. 1) in south-central Oklahoma provides water for public supply, farms, mining, wildlife conservation, recreation, and the scenic beauty of springs, streams, and waterfalls. A new understanding of the aquifer flow system was developed as part of the Arbuckle-Simpson Hydrology Study, done in 2003 through 2008 as a collaborative research project between the State of Oklahoma and the Federal government (Oklahoma Water Resources Board, 2003). The U.S. Geological Survey collected 36 water samples from 32 wells and springs (fig. 2) in the Arbuckle-Simpson aquifer in 2004 through 2006 for geochemical analyses of major ions, trace elements, isotopes of oxygen and hydrogen, dissolved gases, and dating tracers (Christenson and others, 2009). The geochemical analyses were used to characterize the water quality in the aquifer, to describe the origin and movement of ground water from recharge areas to discharge at wells and springs, and to determine the age of water in the aquifer.

Is the Water Safe to Drink?

Most of the water in the Arbuckle-Simpson aquifer is suitable for all regulated uses, including public drinking water supplies. Median concentration for dissolved solids was 347 milligrams per liter (mg/L), equivalent to parts per million. Hardness of water samples from the Arbuckle-Simpson aquifer ranged from 210 to 610 mg/L as calcium carbonate, which is considered to be very hard (Hem, 1985). Although not a health hazard, hard water can cause scaling in pipes and water fixtures. Two domestic wells produced water with nitrate concentrations that exceeded the nitrate maximum contaminant level (MCL) of 10 mg/L (U.S. Environmental Protection Agency, 2006), a health concern primarily for infants and pregnant women.

Samples from two wells exceeded the secondary maximum contaminant level (SMCL) for chloride of 250 mg/L, and also exceeded the SMCL of 500 mg/L for dissolved solids (U.S. Environmental Protection Agency, 2006). These two wells are flowing artesian wells located at the edge of the freshwater flow system and water from these wells is not used for public supply.

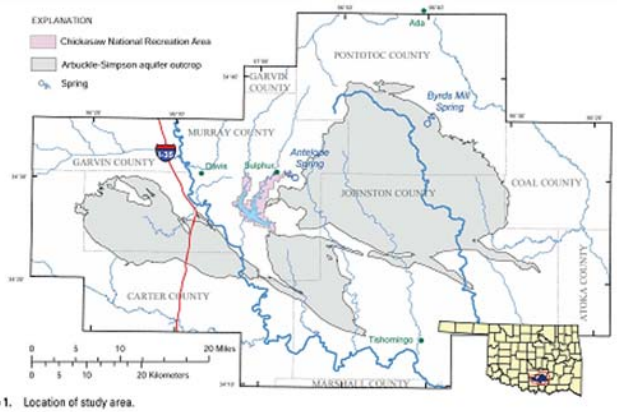


Figure 1. Location of study area.

U.S. Department of the Interior
U.S. Geological Survey

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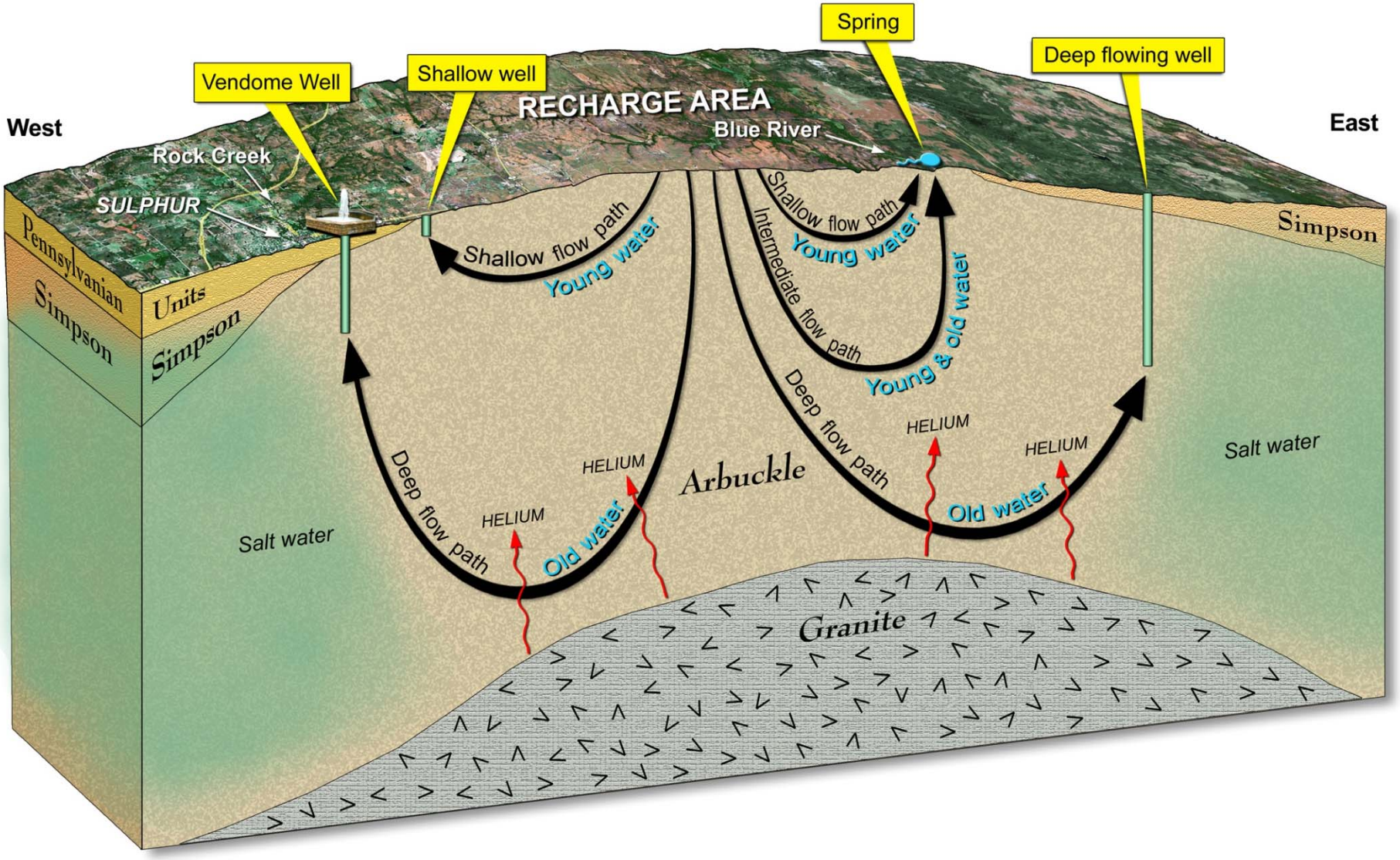
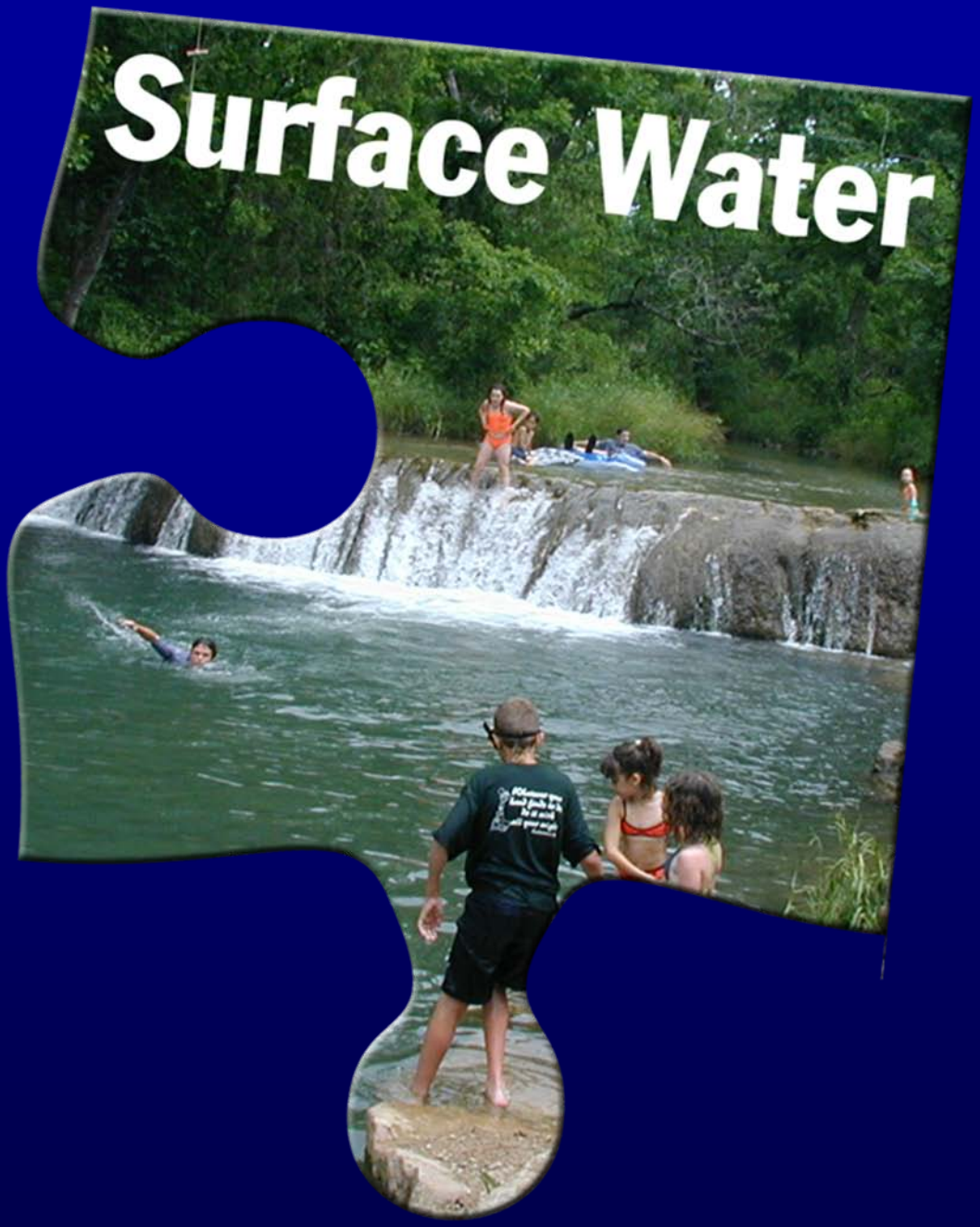
Fact Sheet 2009-3013
April 2009


Spring
Deep flowing well
Vendome Well
Shallow well
RECHARGE AREA
Blue River
West
East
Rock Creek
SULPHUR
Pennsylvanian
Units
Simpson
Simpson
Simpson
Shallow flow path
Young water
Shallow flow path
Young water
Intermediate flow path
Young & old water
Deep flow path
HELIUM
HELIUM
HELIUM
Arbuckle
Deep flow path
Old water
Old water
Salt water
Salt water
Granite

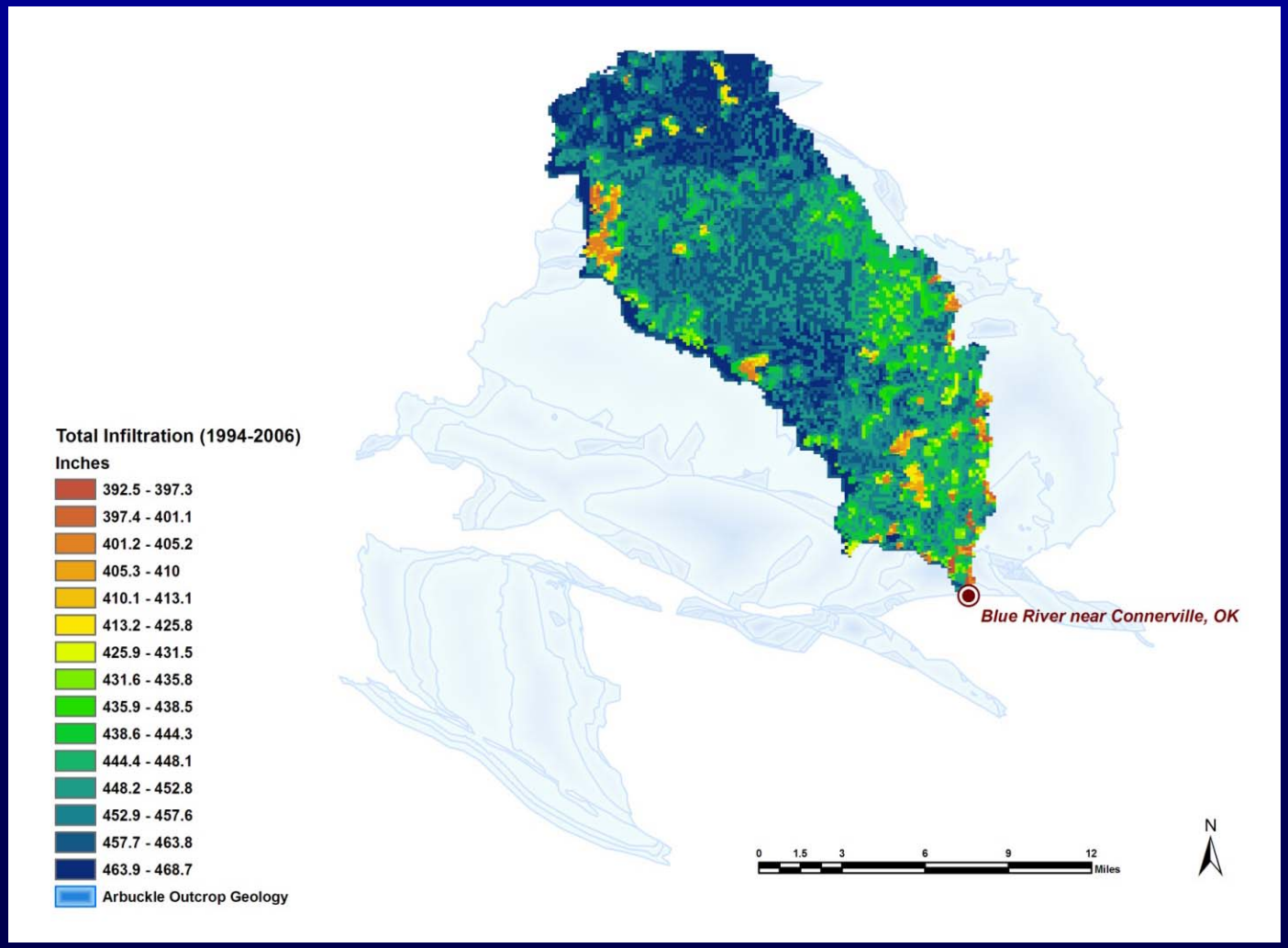
Vendome Well

- 10,500 years old (Carbon-14)
- 44°F (dissolved argon, neon, and xenon)
- 99% freshwater
- 1% brine
- Long, deep flow paths (excess helium)

Surface Water



Rainfall-Runoff Model



Senate Bill 288

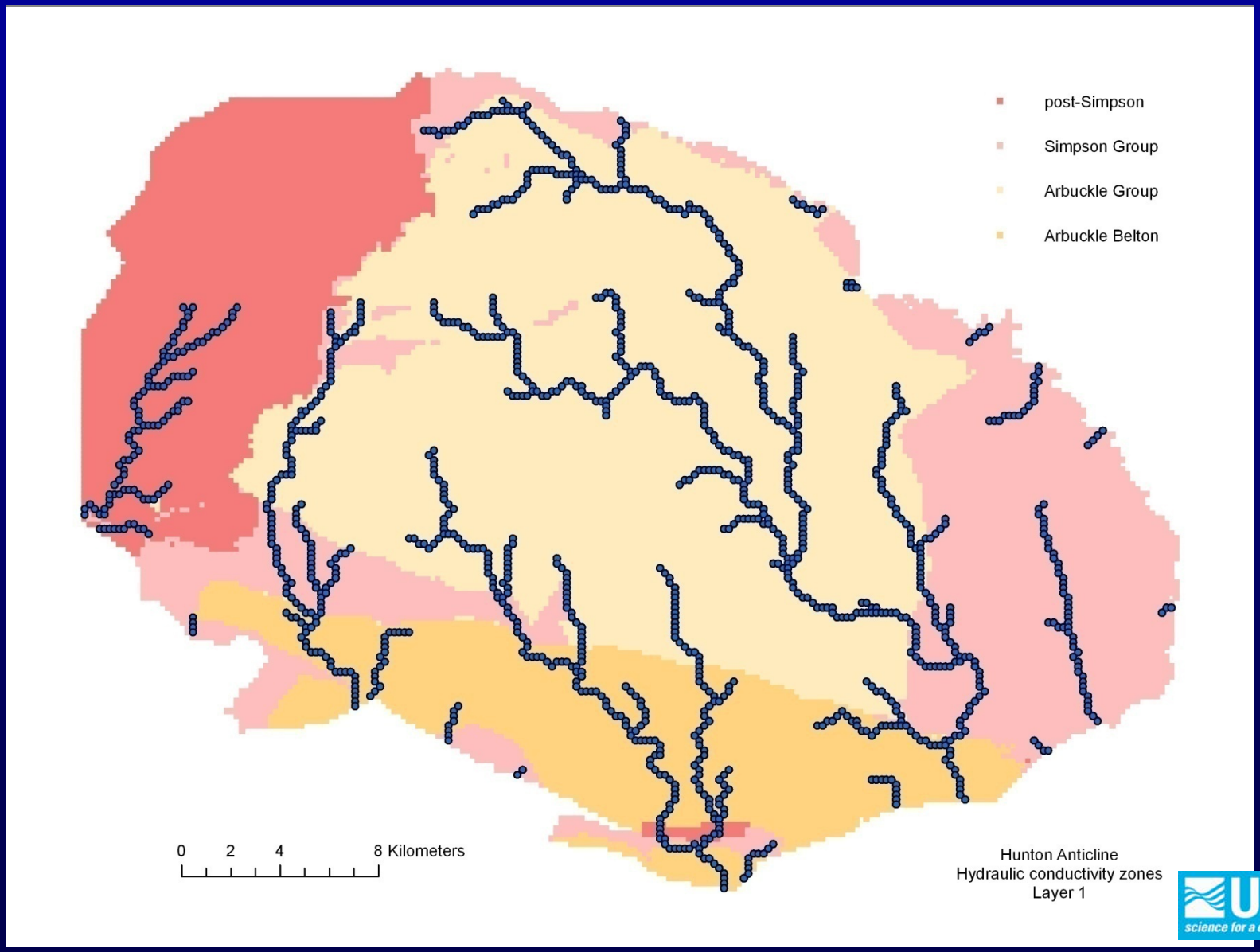
- Approve a maximum annual yield that will not reduce the natural flow of water from springs or streams emanating from the basin.

Streamflow Criteria

- Fish and habitat
- Water rights
- Recreation
- Frequency and duration of droughts

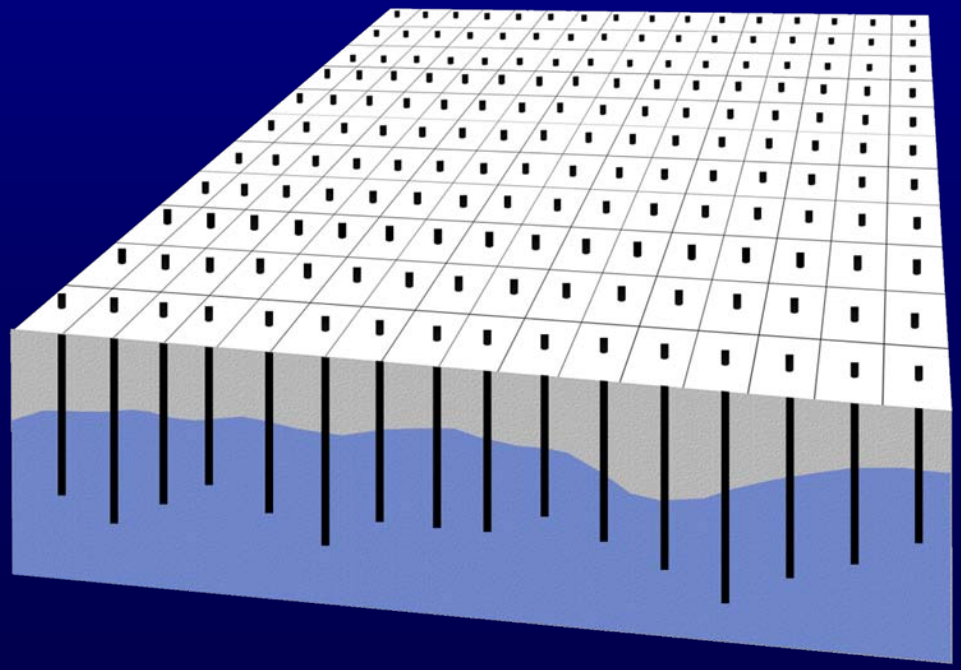
Hunton Anticline MODFLOW Model

Layer 1 Discretization



Equal Proportionate Share

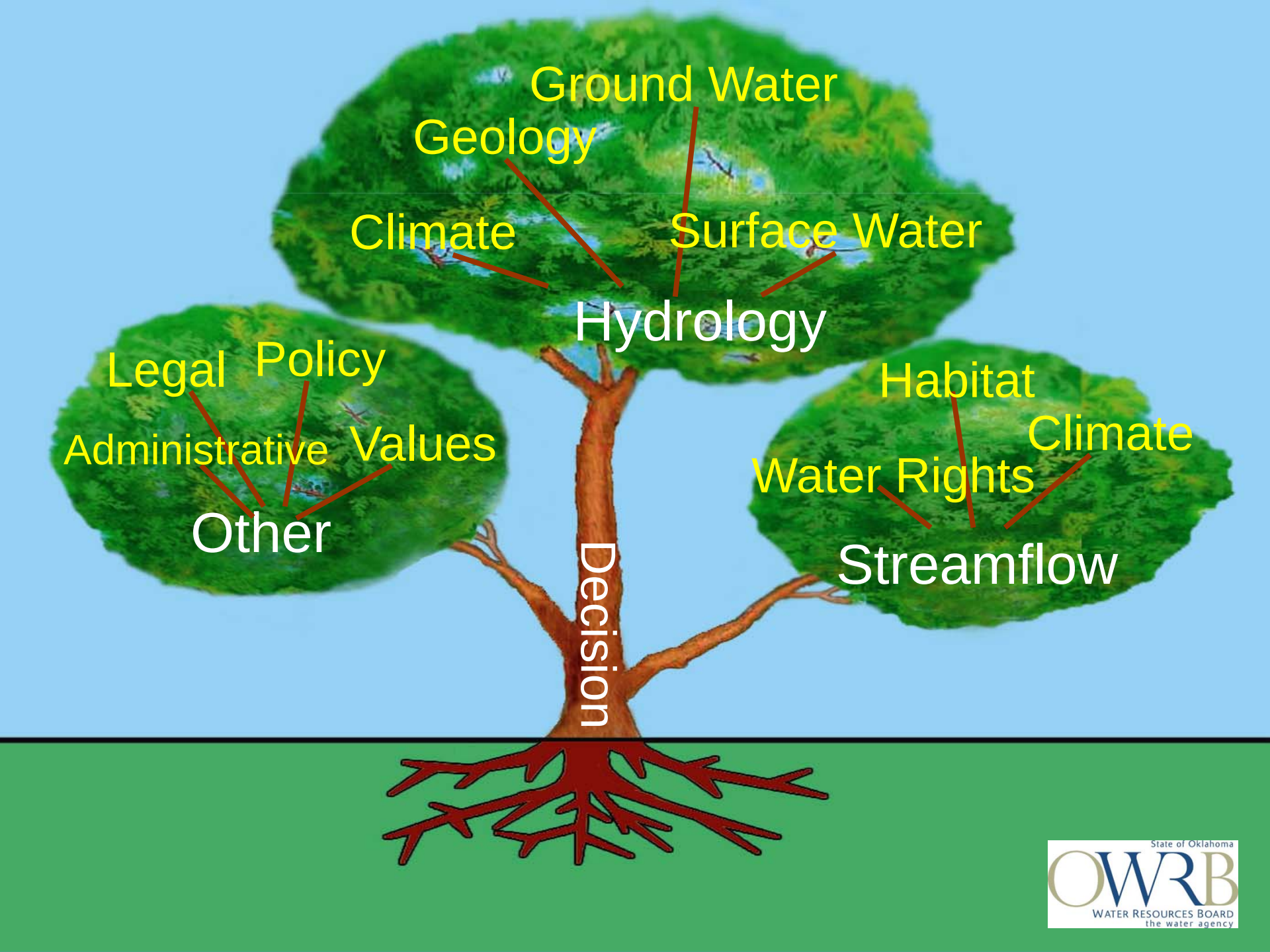
- Each groundwater user is entitled to withdraw an equal share of water proportional to the amount of land owned.

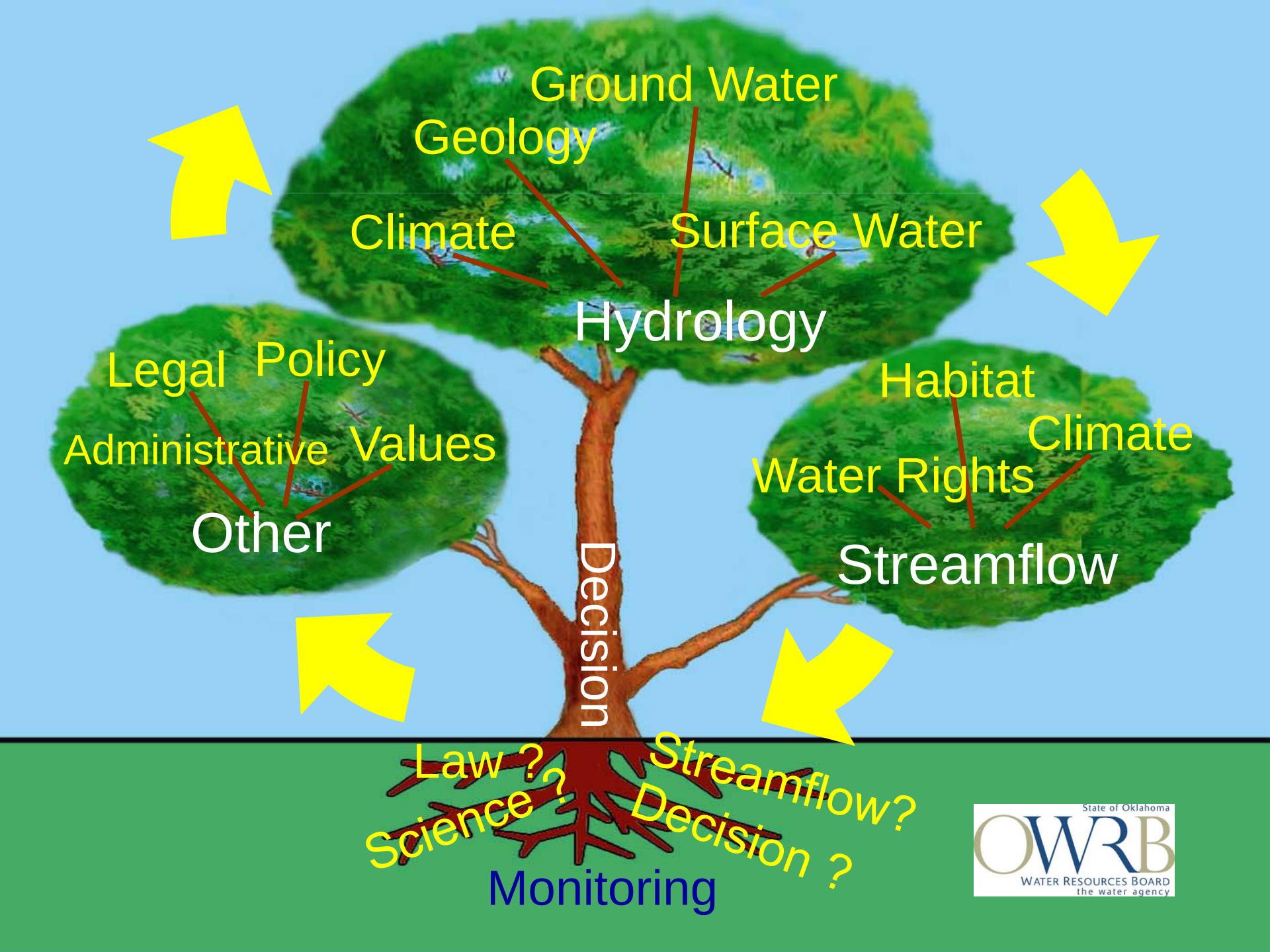


Other Management Strategies

- Well spacing
- Pumping rates
- Set-back distances from springs and streams
- Conditional permits
- Conjunctive use of groundwater and surface water to optimize use and to minimize adverse effects

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency


Ground Water
Geology
Climate
Surface Water
Hydrology
Legal
Policy
Administrative
Values
Other
Habitat
Climate
Water Rights
Streamflow
Decision


Ground Water
Geology
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Other
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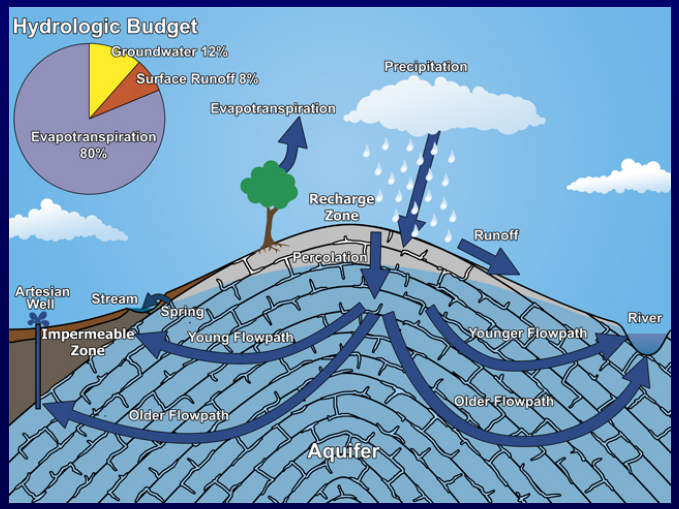
Climate
Water Rights
Streamflow
Decision
Law ?
Science ?
Streamflow?
Decision ?
Monitoring
State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

Role of Science in Managing the Arbuckle-Simpson Aquifer

- Provide a conceptual model of the aquifer system
- Predict consequences of various management strategies
- Evaluate methodologies and new technologies to address specific problems
- Monitor the system
- Inform



Challenges & Opportunities